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SUPERSONIC AERODYNAMIC CHARACTERISTICS OF A SATURN IB LAUNCH VEHICLE MODEL WITH THIRD-STAGE MODIFICATIONS

by Roger H. Fournier

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Langley Station, Hampton, Va.

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SUPERSONIC AERODYNAMIC CHARACTERISTICS OF A SATURN IB LAUNCH VEHICLE MODEL WITH THIRD-STAGE MODIFICATIONS

By Roger H. Fournier
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N66-33486

SUMMARY

A wind-tunnel investigation of a 0.0132-scale model of a Saturn IB launch vehicle was made to determine the effects of a change in third-stage cone angle and the influence of the Apollo spacecraft with escape tower on the aerodynamic characteristics in pitch. The tests were performed at Mach numbers from 1.57 to 4.63 through an angle-of-attack range from about -6° to 20°.

The results indicate that a change in the third-stage cone angle of the complete configuration from 8.6° to 12.45° increased the longitudinal stability level by about 11-percent reference diameter, but resulted primarily in an increase in axial force. The increment in axial-force coefficient progressively decreased with increasing Mach number. In addition, the data indicate that should the Apollo spacecraft abort from the launch vehicle, the resulting launch configuration would undergo a considerable increase in longitudinal stability level and in axial force at all test angles of attack and Mach numbers.

Author

INTRODUCTION

A program to determine the static aerodynamic characteristics of the Saturn launch vehicle with various payloads is being conducted by the National Aeronautics and Space Administration. Results of tests of various configurations of two-stage and three-stage Saturn launch vehicles are presented in references 1 to 4. As a continuation of this program an investigation was conducted to determine the effects of a change in third-stage cone angle on the aerodynamic characteristics in pitch of a 0.0132-scale model of a three-stage Saturn IB launch vehicle with an Apollo payload. In addition, tests of the model with the smaller third-stage cone angle were also performed without the Apollo payload. The effect of fins on the aerodynamic characteristics of the model with the smaller third-stage cone angle was also determined. The tests were performed in the Langley Unitary Plan wind tunnel through an angle-of-attack range from about -6° to 20° at Mach numbers from 1.57 to 4.63. The Reynolds number based on reference diameter for the tests at Mach numbers of 1.57 and 2.16 was 0.721×10^{6} and at Mach numbers of 2.30, 2.86, 3.96, and

4.63 was 0.848×10^6. In order to expedite publication, the data are presented without analysis or comment.

SYMBOLS

Measurements for this investigation were taken in the U.S. Customary System of Units. Equivalent values are indicated herein parenthetically in the International System (SI) in the interest of promoting use of this system in future NASA reports. Details concerning the use of SI, together with physical constants and conversion factors, are given in reference 5. The aerodynamic force and moment data of this investigation are referred to the body axis system with the origin located on the model center line at a distance of 12.510 inches (31.775 centimeters) from the base of the model.

A — reference area, 0.06275 square foot (0.00583 square meter)

A_b — base area, 0.06711 square foot (0.00623 square meter)

C_A — axial-force coefficient, $\frac{\text{Axial force}}{qA}$

$C_{A,b}$ — base axial-force coefficient, $\frac{(p - p_b)A_b}{qA}$

$C_{A,\alpha=0}$ — axial-force coefficient at $\alpha = 0^\circ$

C_m — pitching-moment coefficient, $\frac{\text{Pitching moment}}{qAd}$

C_{m_α} — slope of pitching-moment-coefficient curve at $\alpha = 0^\circ$, per degree

C_N — normal-force coefficient, $\frac{\text{Normal force}}{qA}$

C_{N_α} — slope of normal-force-coefficient curve at $\alpha = 0^\circ$, per degree

D — diameter, inches (centimeters)

d — reference diameter, 3.392 inches (8.616 centimeters)

M — free-stream Mach number

p — free-stream static pressure, pounds/foot^2 (kilonewtons/meter^2)

p_b	base pressure, pounds/foot^2 (kilonewtons/meter^2)
q	free-stream dynamic pressure, pounds/foot^2 (kilonewtons/meter^2)
$\frac{x_{cp}}{d}$	location of center of pressure in body diameters from moment center (positive values indicate a forward location)
R	Reynolds number based on reference diameter
r	radius, inches (centimeters)
α	angle of attack of model center line, degrees
p_t	stagnation pressure, pounds/foot^2 (kilonewtons/meter^2)
T_t	stagnation temperature, $^{\circ}$F ($^{\circ}$K)

APPARATUS AND TESTS

Model

Pertinent dimensions of the 0.0132-scale model of the Saturn IB launch vehicle are presented in figure 1. Photographs of the model are presented in figure 2. The complete model simulated a three-stage launch configuration including a payload consisting of the Apollo spacecraft and escape tower. The first two stages of the model were common throughout the investigation. The third stage was provided with two interstage adapters, one consisting of a frustum of a cone having a half-cone angle of 8.6° and the other a half-cone angle of 12.45°. The overall length of the complete configuration changed by 0.079 in. (0.201 cm).

Tunnel

The tests were conducted in both the low and high Mach number test sections of the Langley Unitary Plan wind tunnel, which is a variable-pressure, continuous, return-flow type. The test sections are 4 feet square (1.219 m) and approximately 7 feet (2.134 m) in length. The nozzles leading to the test sections are of the asymmetric sliding block type, which permits continuous variation of Mach number from about 1.5 to 2.9 and 2.3 to 4.7 in the low and high Mach number test sections, respectively.

MEASUREMENTS AND TEST CONDITIONS

Forces and moments acting on the model were measured by means of an internally mounted six-component strain-gage balance. The model suppport system consisted of a sting-balance combination attached to a remotely operated angle-of-attack mechanism connected to the central support system of the tunnel. A pressure transducer was used to measure the model base pressure.

The test configurations were investigated through an angle-of-attack range from about -6° to 20° at an angle of sideslip of 0°. The test conditions are summarized in the following table:

M	p_t		q		R	T_t	
	lb/ft^2	kN/m^2	lb/ft^2	kN/m^2		$^{\circ}$K	$^{\circ}$F
1.57	1443	69.09	613	29.35	0.721×10^6	338	150
2.16	1820	87.14	593	28.39	.721	338	150
2.30	2292	109.74	679	32.51	.848	338	150
2.86	3073	147.14	592	28.35	.828	338	150
3.96	5776	276.56	441	21.12	.848	352	175
4.63	7883	377.44	349	16.71	.848	352	175

CORRECTIONS AND ACCURACIES

The angles of attack have been adjusted for flow angularity and structural deflection of the sting-balance combination due to the aerodynamic loads. Axial-force coefficients have been adjusted to correspond to free-stream static pressure acting at the base of the model. Typical variations of base axial-force coefficient with angle of attack are presented in figure 3. The estimated accuracies of the angle of attack, Mach number, and the coefficients, based on the balance calibration and the repeatability of the data, are within the following limits:

α, deg . . . . ±0.10
C_N . . . . ±0.070
C_m . . . . ±0.030
C_A . . . . ±0.006
M = 1.57 to 2.86 . . . . ±0.015
M = 3.96 to 4.63 . . . . ±0.050

PRESENTATION OF RESULTS

The results of this investigation are presented in the following figures:

SUMMARY OF RESULTS

A wind-tunnel investigation of a 0.0132-scale model of a Saturn IB launch vehicle was made to determine the effect of a change in third-stage cone angle and the influence of the Apollo spacecraft with escape tower on the aerodynamic characteristics in pitch. In general, these data show that a change in the third-stage cone angle of the complete configuration from 8.6° to 12.45° increased the longitudinal stability level by about 11-percent reference diameter, but resulted primarily in an increase in axial-force coefficient. This increment in axial-force coefficient progressively decreases with increasing Mach number. In addition, these data indicate that should the Apollo spacecraft abort from the launch vehicle, the resulting launch configuration (neglecting any change in center-of-gravity location) would undergo a considerable increase in longitudinal stability level and would experience a large increase in axial force at all test angles of attack and Mach numbers.

Langley Research Center,
National Aeronautics and Space Administration,
Langley Station, Hampton, Va., April 26, 1966.

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1. Morgan, James R.; and Fournier, Roger H.: Static Longitudinal Aerodynamic Characteristics of a Model of a Two-Stage Version of a Saturn Launch Vehicle With a Proposed Apollo Payload at Mach Numbers From 1.57 to 2.87. NASA TM X-602, 1961.

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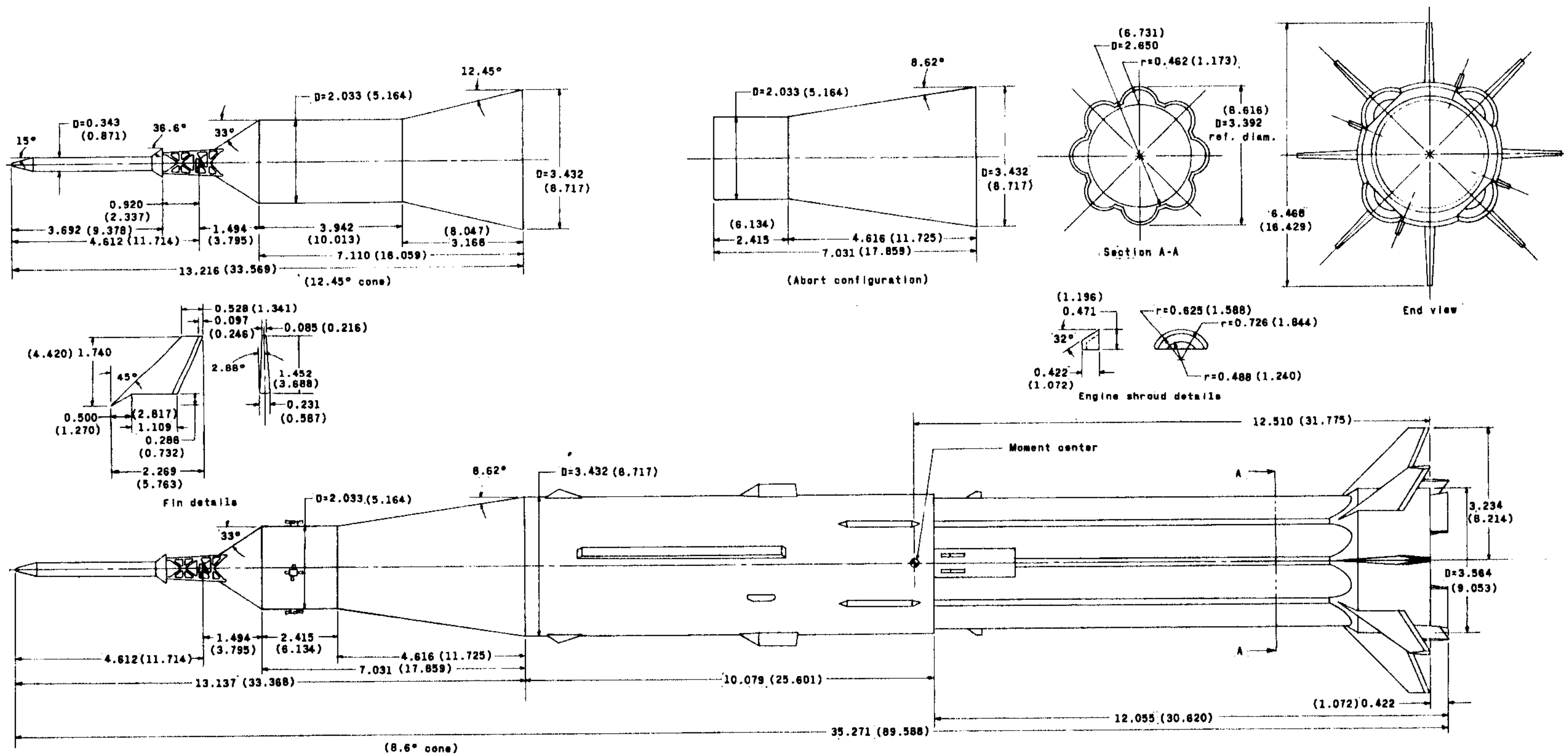
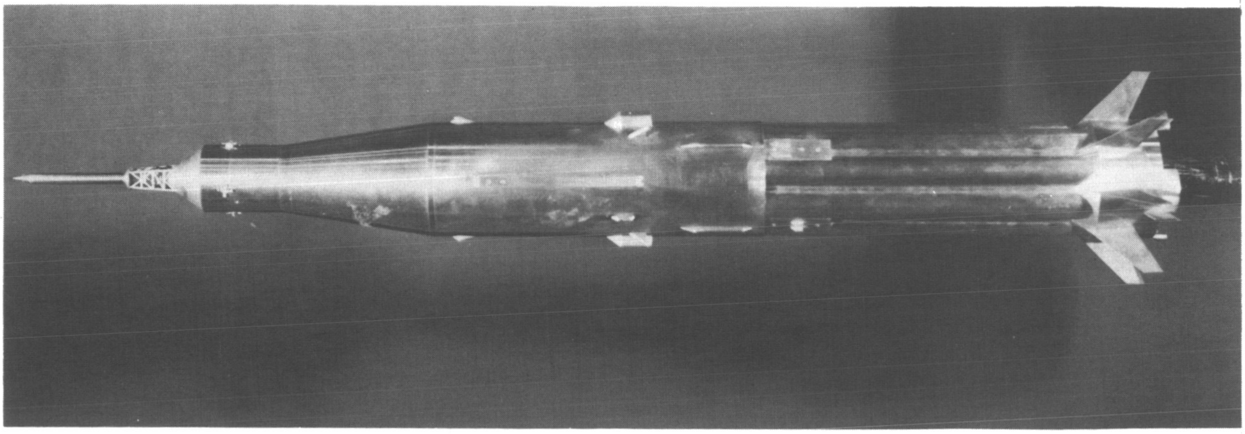
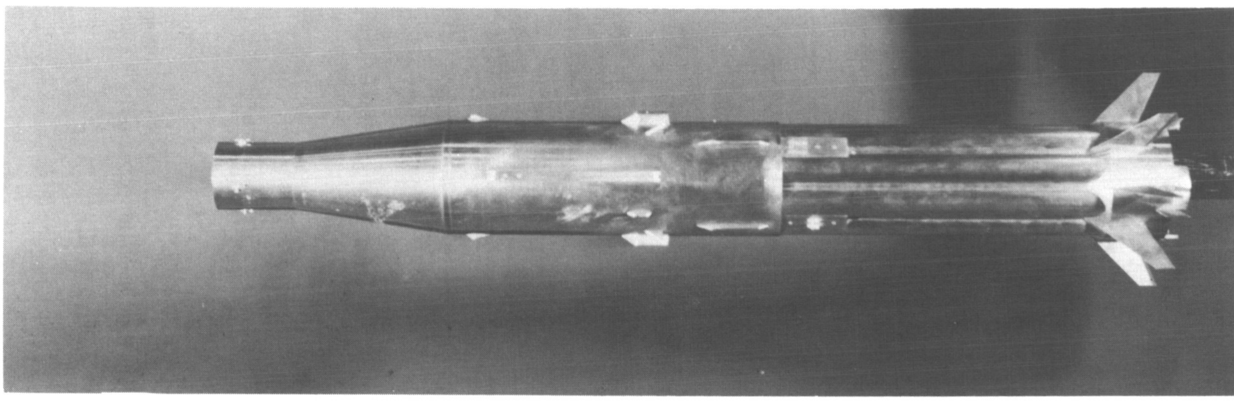


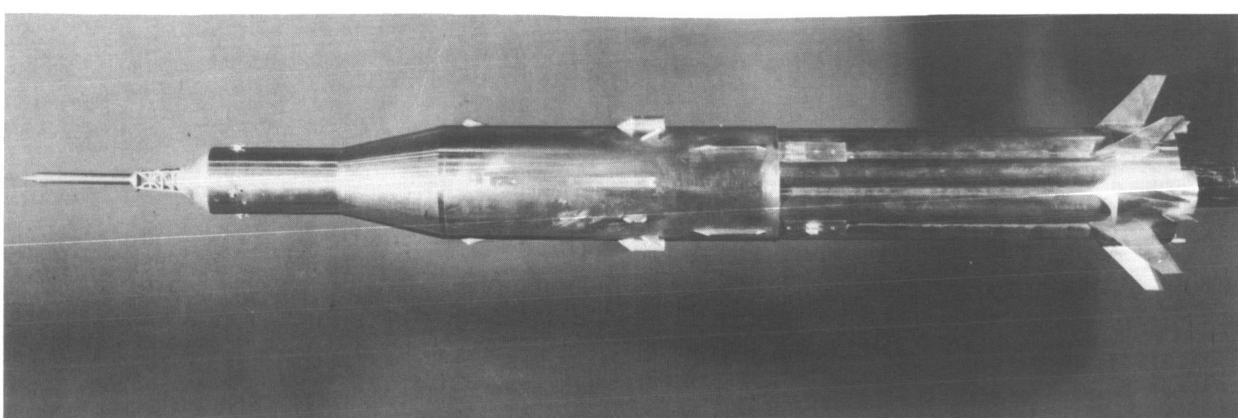
Figure 1.- Pertinent dimensions of 0.0132-scale model of Saturn IB launch vehicle. Dimensions are given first in inches and parenthetically in centimeters unless otherwise noted.



(a) Complete configuration 8.6^{0} third-stage cone. L-64-2705



(b) Abort configuration 8.6^{0} third-stage cone. L-64-2707



(c) Complete configuration 12.45^{0} third-stage cone. L-64-2709

Figure 2.- Photographs of model.

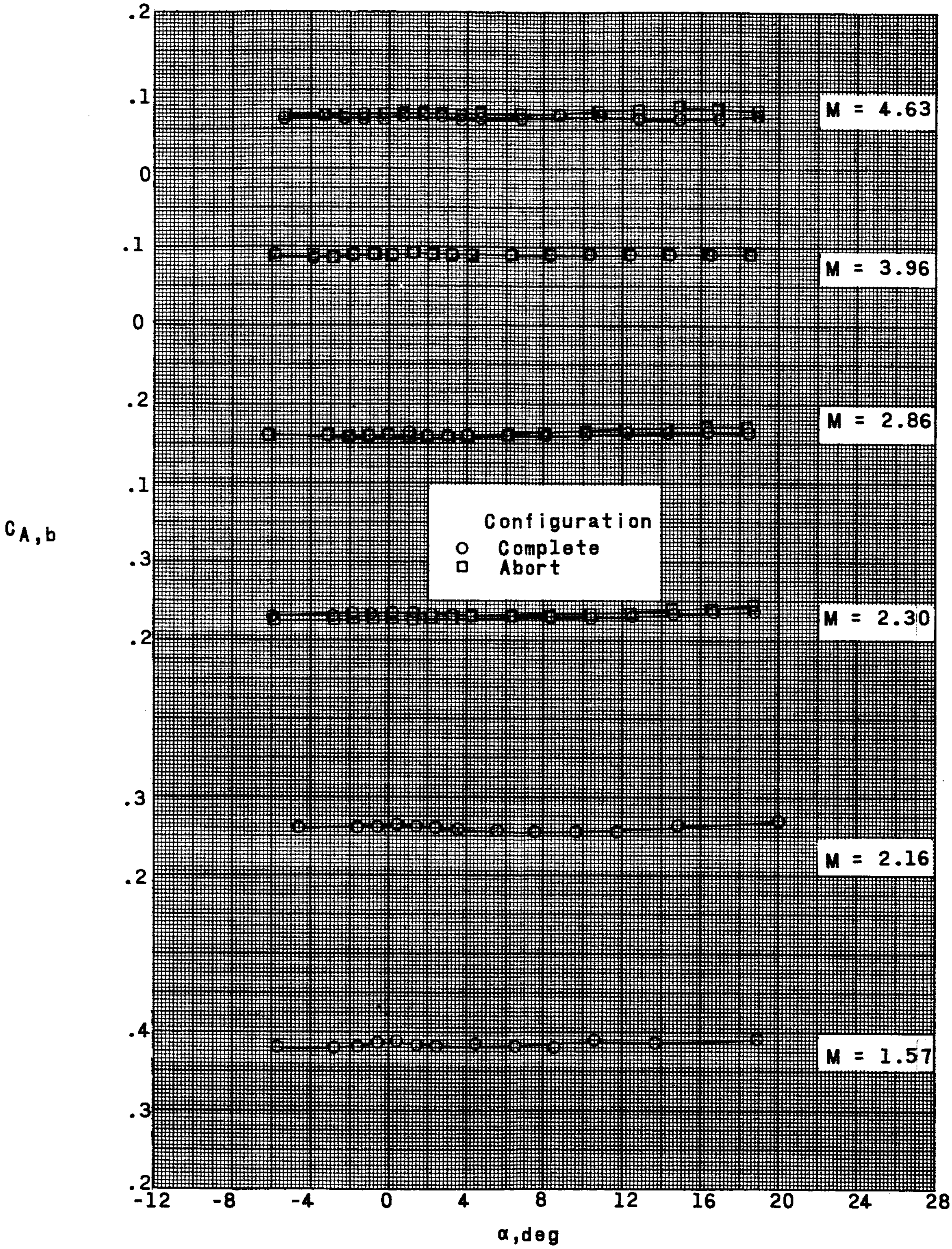
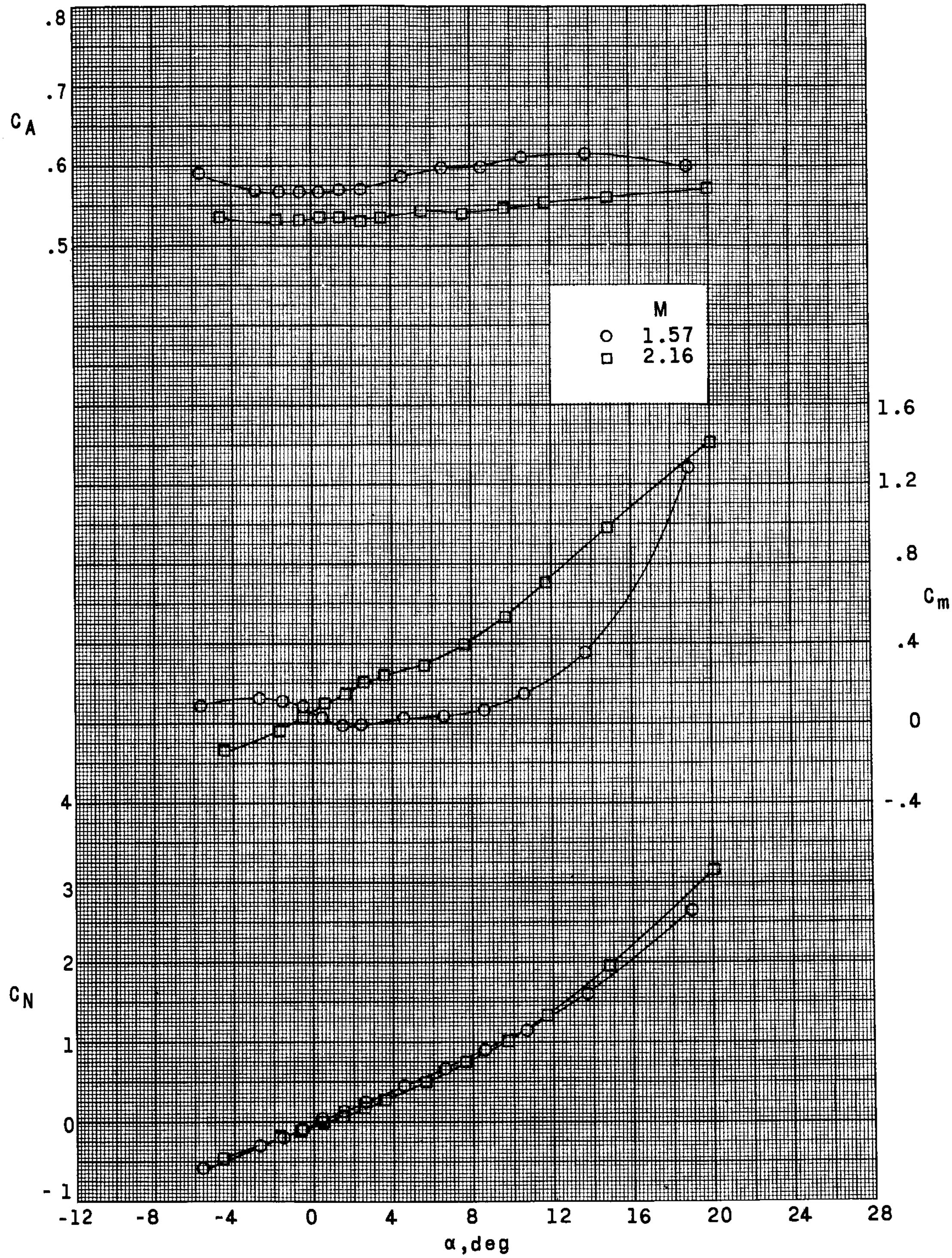
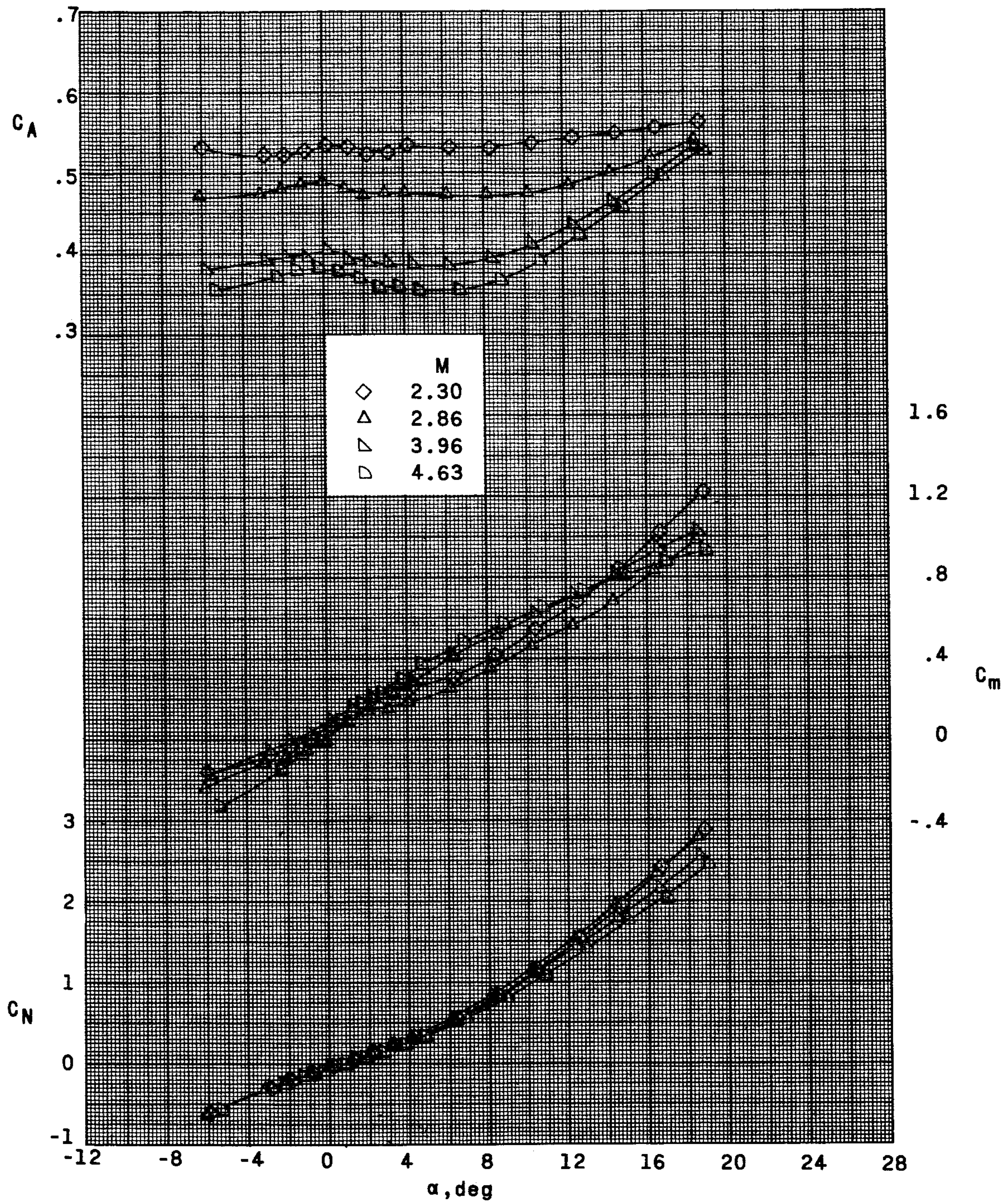


Figure 3.- Variation of base axial-force coefficient with angle of attack of a Saturn IB launch configuration with 8.6° third-stage cone.



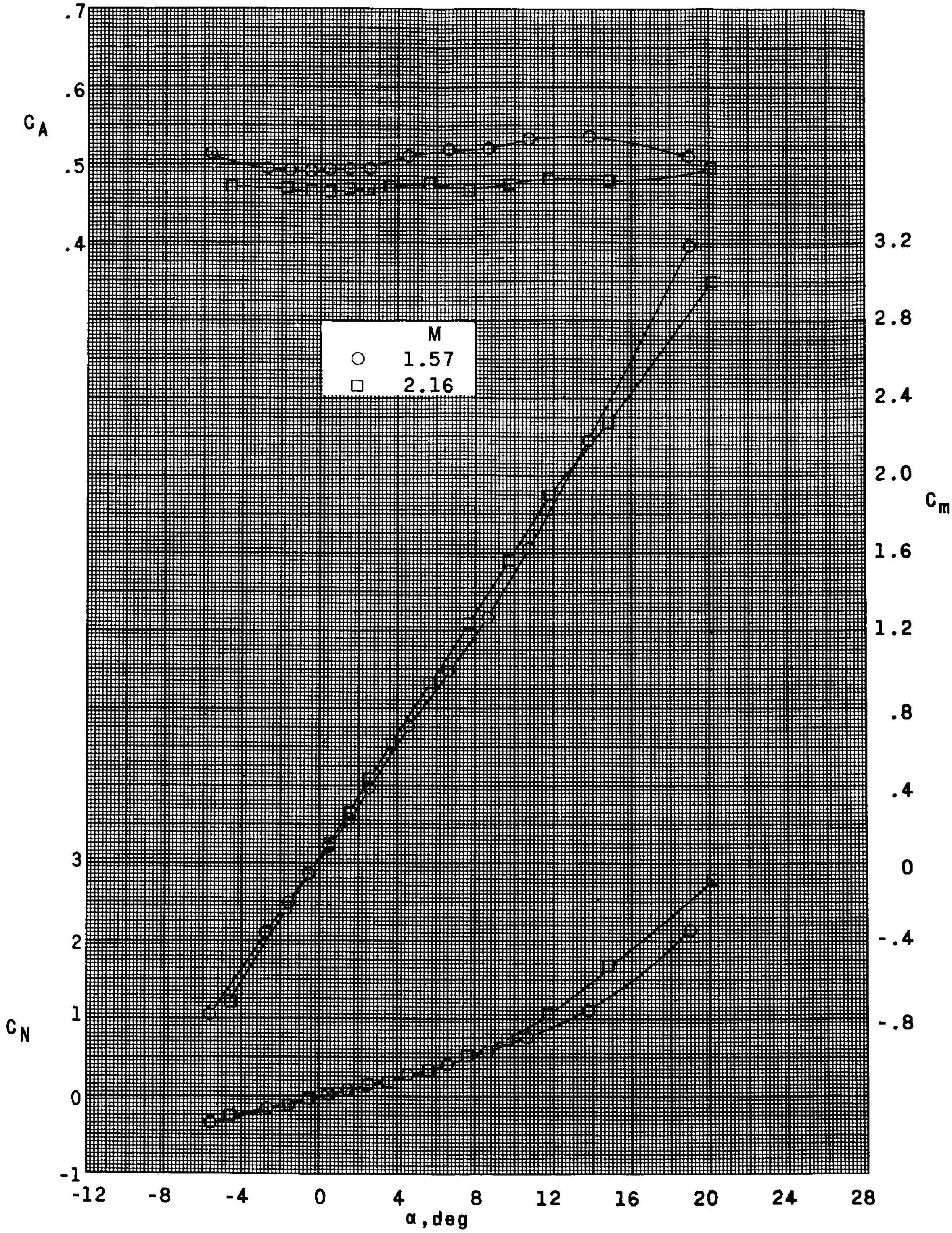
(a) Complete model.

Figure 4.- Longitudinal aerodynamic characteristics in pitch of a Saturn IB launch configuration with 8.6° third-stage cone.



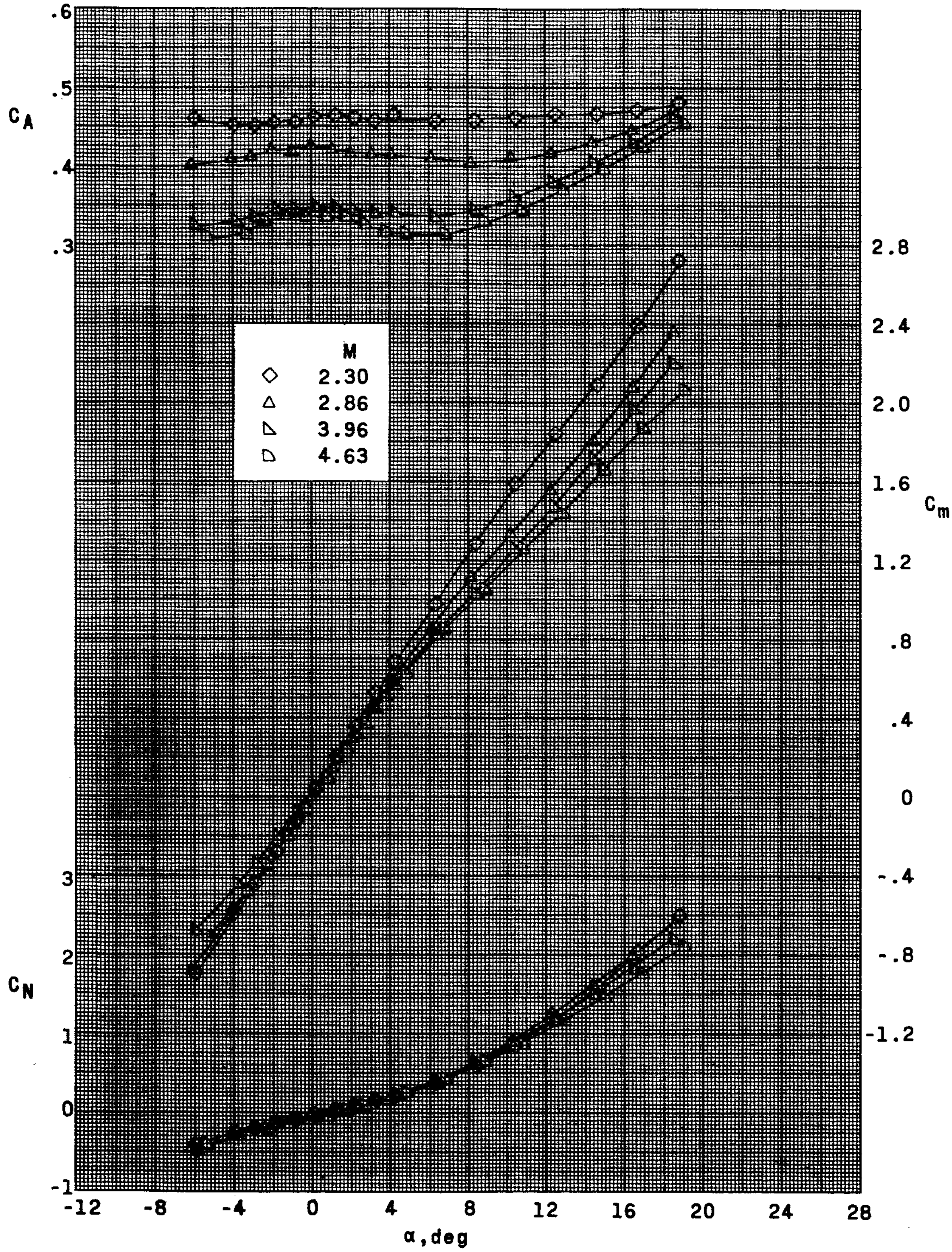
(a) Concluded.

Figure 4.- Continued.



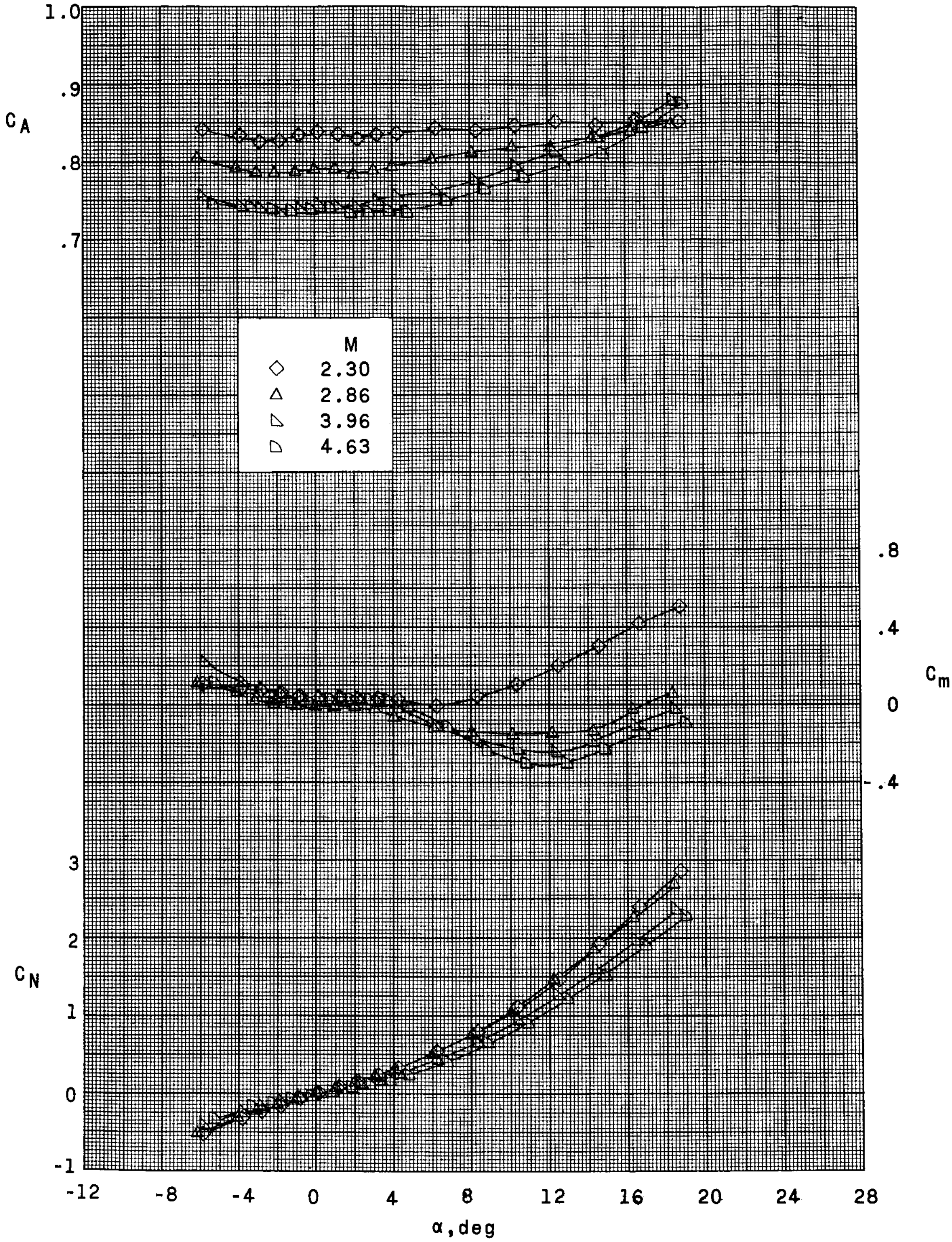
(b) Fins off.

Figure 4.- Continued.



(b) Concluded.

Figure 4.- Continued.



(c) Abort configuration.

Figure 4.- Concluded.

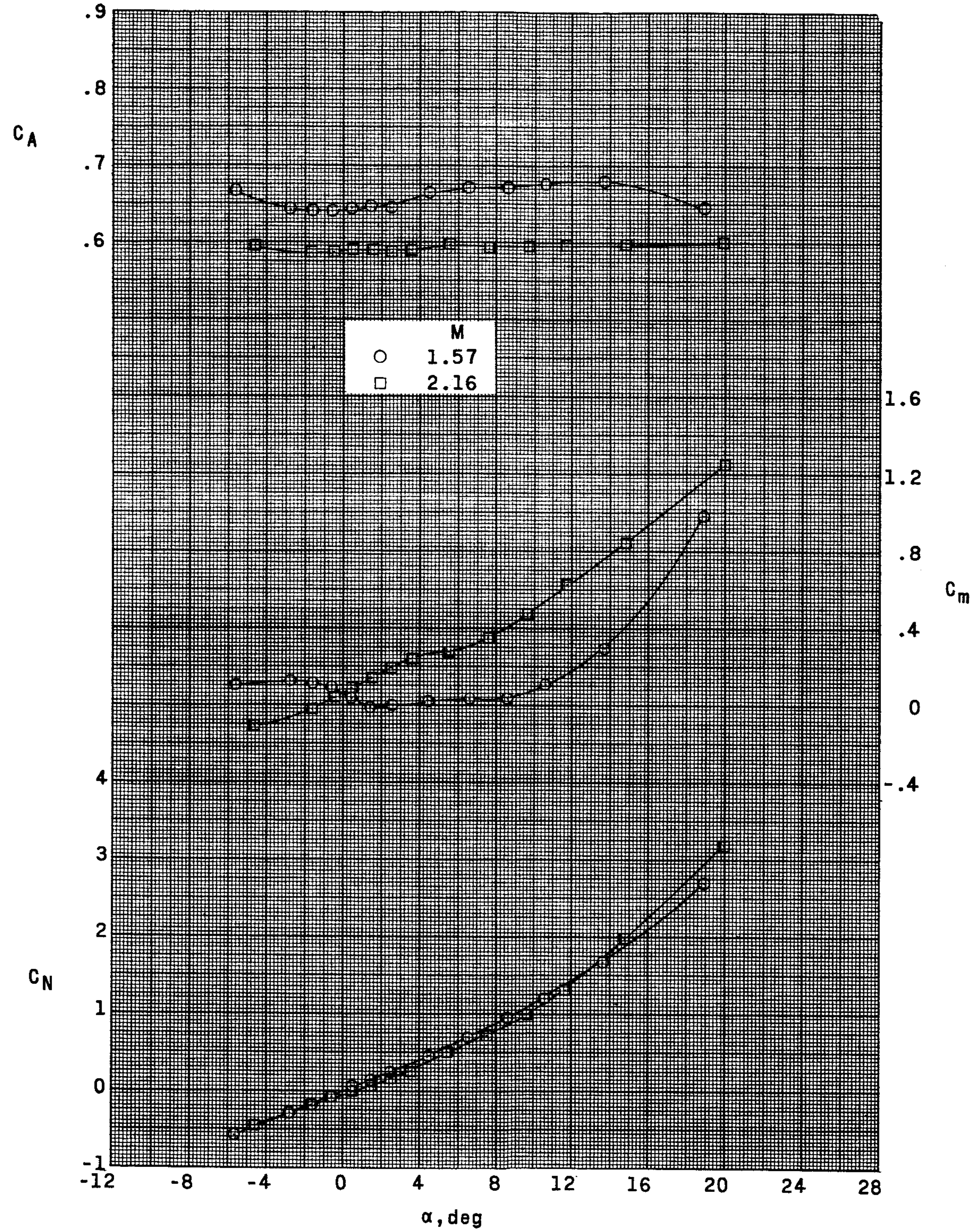


Figure 5.- Longitudinal aerodynamic characteristics in pitch of a Saturn IB launch configuration with 12.45° third-stage cone. Complete model.

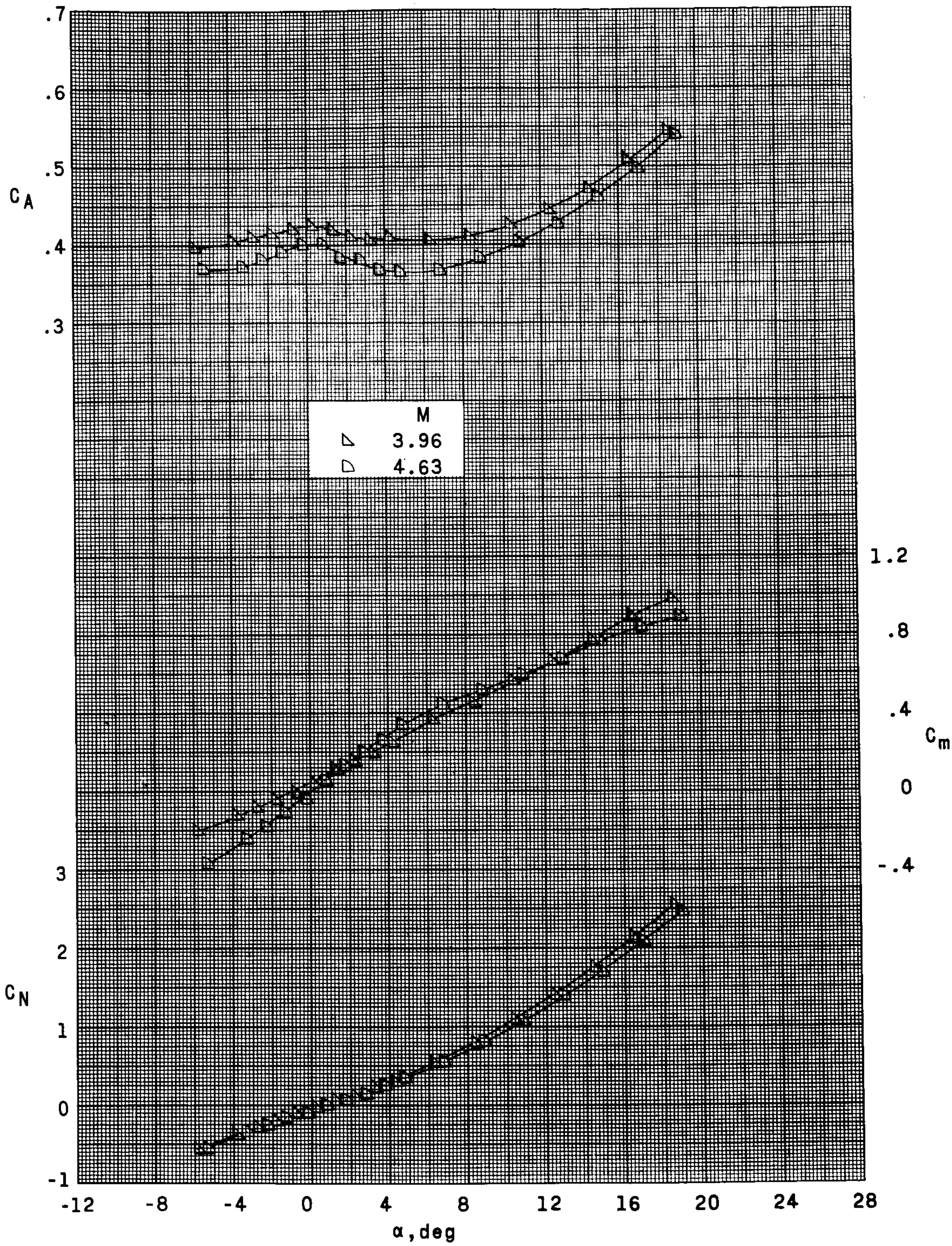


Figure 5.- Concluded.

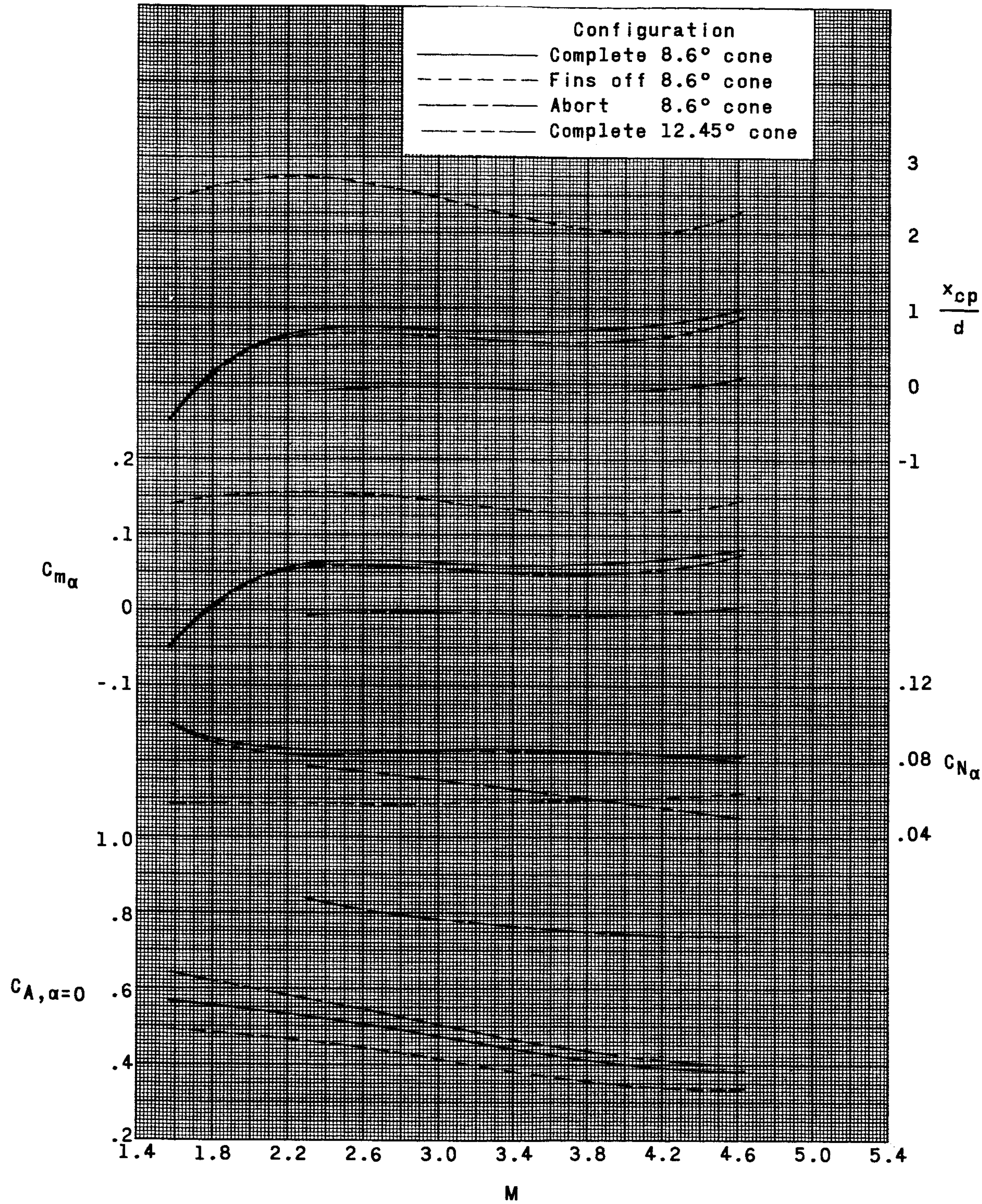


Figure 6.- Variation of longitudinal parameters with Mach number of various Saturn IB launch configurations.